Space Technology Research Grants

Automated Precision Maneuvering and Landing in Extreme and Constrained Environments

Completed Technology Project (2014 - 2018)

Project Introduction

Autonomous, precise maneuvering and landing in extreme and constrained environments is a key enabler for future NASA missions. Missions to map the interior of a lunar skylight during flyover, extract resources on asteroids, and explore crater rims cannot succeed without exact maneuvers and high accuracy landing. Some of the most compelling targets for future science and exploration in our solar system lie in terrain that is inaccessible for state of art robotic rovers. For example, the LCROSS experiment found evidence of water ice in the permanently shadowed Cabeus Crater on the Moon. During successive flybys, the Mars Global Surveyor detected bright gully deposits on the walls of two separate unnamed craters, indicating geological or hydrological flows on Mars. These destinations challenge access for even the most capable rovers. There is a need to develop autonomous, precise maneuvering and landing technologies to gain access to regions of interest on planetary surfaces, solar system bodies, and artificial objects in space. In some cases this need is due to the physical constraints of the mission. For example, a mission to map the interior of a skylight during flyover requires tightly-constrained control sequences that are not possible through remote operations due to two-way signal communication time. This research proposes to research and develop methods for sensor-based guidance, navigation, and control that will achieve high-precision maneuvering and landing in extreme and constrained environments. These technologies will enable autonomy without operator involvement in previously inaccessible environments near and around asteroids, skylights on the Moon and Mars, and in deep space. The approach will be to develop methods for sampling-based planners to plan low-cost trajectories that account for uncertainties during precision maneuvers and landing in extreme and constrained environments. Markov Decision Processes are too computationally expensive to solve in real-time so this research will explore approximate methods to solve uncertain control problems. This research will also study convex optimization to determine solutions or approximations to globally optimal solutions so that the Problem G&C can be computed in real-time. This research will utilize a sensing package containing IMU, LIDAR, and stereo cameras to collect data and test the efficacy of considered methods. The package will be provided by Carnegie Mellon University's Google Lunar XPRIZE team, led by Red Whittaker. Data will be collected from ground vehicles, helicopters, quadcopters, and ziplines owned by the Field Robotics Center at CMU as well as data from propulsive landing tests aboard the Masten Space Systems Xaero and Xombie rockets through a Flight Opportunities contract secured by Astrobotic Technology. If possible, this research will be integrated into future space missions such as a planned 2018 lunar mission by Astrobotic Technology to demonstrate an autonomous lunar landing. Among the top technical challenges of TA05 is onboard autonomous navigation and maneuvering systems for pinpoint landing and maneuvering. A significant benefit to developing this technology is enabling a new class of missions which would otherwise not be possible due to round-trip light time. In addition, autonomous on-board navigation and maneuvering

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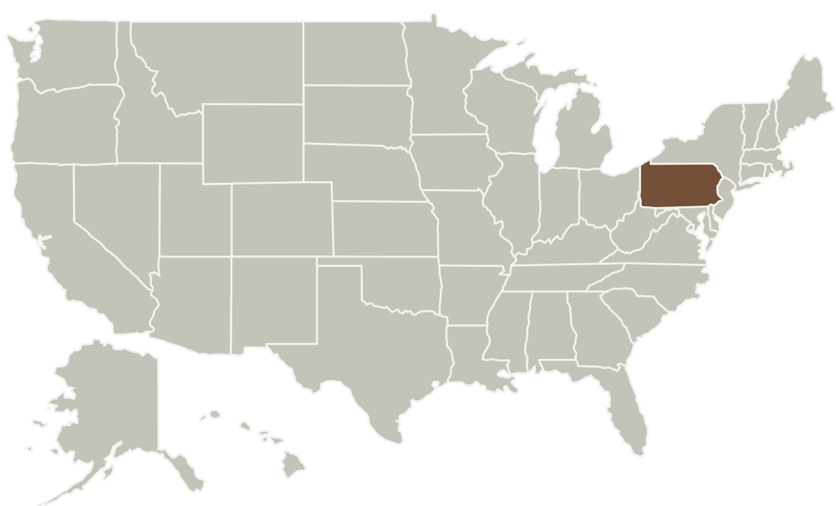
capabilities will increase the agility of the spacecraft, enabling near real-time re-planning and opportunistic science. As mission frequency and commercialization of space continue to grow, ground-in-the-loop guidance of spacecraft will become prohibitively expensive due to scheduling conflicts and increases in maintenance and labor costs. The chance for human error will increase as well. Automation can prevent these outcomes by enabling greater numbers and types of missions while improving robustness and reducing risk, and hence increasing future commercial and scientific return from space.

Anticipated Benefits

A significant benefit to developing this technology is enabling a new class of missions which would otherwise not be possible due to round-trip light time. In addition, autonomous on-board navigation and maneuvering capabilities will increase the agility of the spacecraft, enabling near real-time re-planning and opportunistic science. As mission frequency and commercialization of space continue to grow, ground-in-the-loop guidance of spacecraft will become prohibitively expensive due to scheduling conflicts and increases in maintenance and labor costs. The chance for human error will increase as well. Automation can prevent these outcomes by enabling greater numbers and types of missions while improving robustness and reducing risk, and hence increasing future commercial and scientific return from space.

Primary U.S. Work Locations and Key Partners



Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Carnegie Mellon University

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

William (red) Whittaker

Co-Investigator:

Wennie Tabib

Organizations Performing Work	Role	Type	Location
Carnegie Mellon University	Lead Organization	Academia	Pittsburgh, Pennsylvania

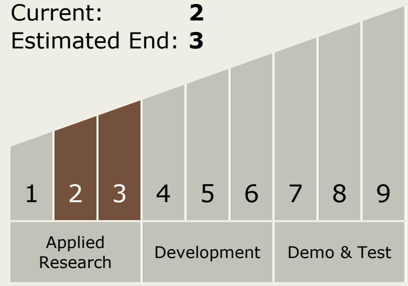
Primary U.S. Work Locations
Pennsylvania

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Technology Areas

Primary:

- TX09 Entry, Descent, and Landing
  └ TX09.4 Vehicle Systems
    └ TX09.4.7 Guidance, Navigation and Control (GN&C) for EDL

Target Destinations

The Moon, Mars, Others Inside the Solar System